BABCOCK & WILCOX CROSSTRAINING COURSE LESSON PLAN		
Lesson Number: 326-21	Title: Advanced Control System	
Written by: G. O. Schneider	Approved by:	Date: 10/15/1998

1.0 References
- 1.1 B&W Crosstraining Manual, Chapter 21
- 1.2 Oconee Lesson Plan

2.0 Training Aids
- 2.1 Transparency package for Lesson 326-21

3.0 Objectives
- 3.1 Explain the function of the following ICS subsystems
  - 3.1.1 Core Thermal Power Demand (CTPD)
  - 3.1.2 Integrated Master
  - 3.1.3 Feedwater Control
  - 3.1.4 Reactor Control
- 3.2 Define the following terms:
  - 3.2.1 Tracking
  - 3.2.2 Runback
  - 3.2.3 Cross Limit
- 3.3 Using a diagram of the ICS, discuss the following:
  - 3.3.1 Normal power increase and decrease
  - 3.3.2 Runback
  - 3.3.3 Placing an ICS station in manual
  - 3.3.4 Load rejection
  - 3.3.5 Turbine trip
  - 3.3.6 Reactor trip

Fig. 21-1

4.0 Presentation

- 4.1 Introduction - Function of ICS is to match reactor thermal power with core thermal power demand while maintaining a balance between heat production and removal. This is accomplished by the four subsystems of the ICS:
  - 4.1.1 Core Thermal Power Demand (ULD) - generation of setpoint
  - 4.1.2 Integrated Master (IM) - steam header pressure control
    - 4.1.2.1 Turbine governor valve control
    - 4.1.2.2 Turbine bypass valve control
    - 4.1.2.3 Generate FW and RX control signals
  - 4.1.3 FW Control
    - 4.1.3.1 Main and startup FW valve control
    - 4.1.3.2 MFP speed control

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Fig. 21-1	4.1.4 RX Demand 4.1.4.1 Rod control 4.1.4.2 T_{avg} control
Fig. 21-2	4.2 Core Thermal Power Demand (CTPD) 4.2.1 Function - setpoint generator for the rest of the ICS 4.2.2 Pushbuttons on Load Control Panel (LCP) for increase or decrease of target setpoint. 4.2.3 Target setpoint appears in lower window called "CTPD SET" 4.2.4 The setpoint being used by the rest of the ACS appears in the upper window called "CTP DEMAND" 4.2.3 Rate is set by using thumbwheels on the LCP. Values from zero to 9.9%, and units % per minute or per hour. Hold pushbutton prevents changes during setpoint or rate entry, and stop power changes.
Table 21-1 Page 21-13	4.2.4 Automatic Load Limiting - limits maximum target setpoint. Transfer function T1 selects setpoint and T11 selects rate. Operator input is blocked.
	4.2.5 Tracking - ACS cannot function normally. Heat balance cannot be maintained. Target setpoint is the tracking parameter selected by transfer function T2. Operator input and automatic load limiting are blocked.
Page 21-2	4.2.5.1 Tracking conditions: (a) Cross Limits (b) SG Master in manual with at least one SG <u>not</u> on LLL. (c) Blocking <u>both</u> feedwater loop flow control paths with at least one SG <u>not</u> on LLL. (d) RX demand or rod control in manual. (e) turbine master in manual. 4.2.5.2 Tracking rate is 20% per minute. 4.2.5.3 Tracking parameters: (a) FW control independent - FW flow (b) Turbine independent - generated electrical power (c) RX independent - NI flux (d) If more than one system independent, tracking parameter is the highest priority (a, b, c) except when FW and RX are both independent, CTP Best is selected.
Fig. 21-2	4.3 Integrated Master 4.3.1 Functions 4.3.1.1 Sends demand signals to RX and FW subsystems. 4.3.1.2 Controls the turbine and the turbine bypass valves.

Table 21-2

4.3.2 Control Variables
- (a) T_{ave}
- (b) Turbine header pressure (THP)
- (c) Core thermal power (CTP)
- (d) ΔT_C

4.3.3 Calibrating Integrals - compensate for imbalances due to changing efficiency, miscalibration, instrument drift, or SG heat transfer capability. Control variables are assigned to calibrating integrals.

4.3.3.1 Normal operation - T_{ave} is assigned to RX integral, THP is assigned to LRM (turbine integral), CTP is assigned to FW integral, and ΔT_C is assigned to the ΔT_C integral.

4.3.3.2 During other modes of operation, control variables are assigned according to priority as shown in Table 21-2.

4.3.4 Cross Terms

4.3.4.1 THP Error - applied to RX and FW demand signals, limited to ± 50 psi.

4.3.4.2 T_{ave} Error - applied to FW demand with a ± 1.2°F deadband. If FW has T_{ave} control, deadband is removed.

4.3.4.3 RCS Pressure Error - applied to RX, FW, and turbine.

4.3.5 Turbine control

4.3.5.1 Error between CTP demand and feedback from pulser through the compensator (anticipatory signal).

4.3.5.2 THP Error (dominant signal)

4.3.5.3 THP error greater than ± 50 psi for more than 5 seconds will cause turbine master to switch to manual unless:
- (a) Crosslimit
- (b) Loss of RCP
- (c) Loss of FWP
- (d) Asymmetric rod
- (e) Loss of RCS flow
- (f) Both output breakers open
- (g) Maximum runback

4.3.5.4 If EHC assumes control due to stator coolant runback or power load unbalance, turbine master <u>will</u> go to manual.

Table 21-3
Table 21-4
T8

4.3.6 Turbine bypass valves (TBVs)

4.3.6.1 Reactor trip - TBV bias is 125 psi. (Control at 1010 psig)

4.3.6.2 Turbine load status flag FALSE or turbine trip - TBV bias is zero. (Control at 885 psig)

4.3.6.3 Turbine load status flag TRUE - TBV bias is 50 psi.

4.3.6.4 Transfer function T7 selects THP when turbine master is in automatic, SG outlet pressure when in manual.

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Table 21-3

4.3.7 Turbine loading and unloading

4.3.1 Reactor power 10% to 20%, TBVs controlling at 885 psig, turbine rolled to synchronous speed. When breakers are closed, turbine automatically picks up 30 MW. Turbine can now be loaded using the turbine master or the load button on the LCP. When TBVs are closed, status flag becomes TRUE. TBV bias becomes 50 psi. The unload button will make the status flag FALSE.

Fig. 9-2

4.4 FW Control

4.4.1 Demand corrections

4.4.1.1 Calibrating integral - normally CTP error. If RX in manual, T_{ave} error. If turbine in manual (status flag TRUE), THP error.

4.4.1.2 THP error - up to ± 50 psi.

4.4.1.3 T_{ave} error - with ± 1.2°F deadband unless FW takes control of T_{ave}.

4.4.1.4 RCS pressure error - when pressure exceeds 2250 psig.

4.4.1.5 CTP error

4.4.1.6 RX crosslimit - neutron error > 5%

4.4.1.7 FW temperature

4.4.2 Loop demands

4.4.2.1 Loop A demand is determined by a multiplier, which is controlled by RCS loop flow error and ΔT_C.

4.4.2.2 Loop B demand is the difference between total demand and loop A demand.

4.4.2.3 RCS loop flow error works all the time.

4.4.2.4 ΔT_C is blocked when the control station is in manual, either loop master is in manual, either valve controller is in manual, or either SG is on level control.

4.4.3 Level errors - Normally, flow error is used to drive the valve controllers, but abnormal conditions can cause level errors to be used.

4.4.3.1 High level limit - operating range, setpoint 92% to 96%, low select unit, maintain level < aspirating ports.

4.4.3.2 Startup level < 25" and LLL - (LLL is SU level < 25" and loop T_{ave} < setpoint.) LLL stays in effect until both conditions clear.

(a) LLL on both SGs releases T_{ave} from control priority and T_{ave} will not increase RX power when T_{ave} < setpoint.

(b) LLL on both SGs limits CTPD rate to 1% per minute.

(c) LLL on both SGs prevents feedwater tracking.

(d) Either SG on LLL blocks ΔT_C correction.

Table 21-4
T6
Fig. 21-3

4.4.3.3 Natural circulation level error - operating range level < 50% or 95% (RB pressure > 3 psig).

4.4.4 Valve sequencing - Main valves have about 10 times the capacity of the startup valves. Startup valves control up to about 15% power, main valves from 15% and up. During startup, the startup valves open as power increases. At about 90%, main block valve opens. At about 98%, sequencing bias causes startup valve to ramp down to 10% and the main valve to open enough to compensate. From this point, the valves open together, startup valves 10 times faster. The shutdown sequence is similar.

4.4.5 FW pump speed control - based on sum of loop demands and differential pressure error.

4.5 Reactor Control Subsystem

4.5.1 Demand corrections

4.5.1.1 Calibrating integral - normally T_{ave} error. If both SGs on LLL, CTP error unless the steam system is also unavailable, then THP error.

4.5.1.2 THP error - up to ± 20 psi.

4.4.1.3 T_{ave} error - (When both SGs on LLL, T_{ave} error can only decrease RX demand if T_{ave} is above setpoint.)

4.4.1.4 RCS pressure error - when pressure exceeds 2250 psig.

4.4.1.5 RX demand limit of 101%.

4.4.1.6 FW crosslimit - FW demand > flow by > 5%. FW flow becomes the tracking parameter.

Fig. 9-2